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Issued July 27, 1917.

HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge.

Bulletin No. 44.

THE LITCHI IN HAWAII.

BY

J. E. HIGGINS,
Horticulturist.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, *October 30, 1916.*

SIR: I have the honor to submit herewith and to recommend for publication as Bulletin No. 44 of the Hawaii Agricultural Experiment Station a paper entitled "The Litchi in Hawaii," by J. E. Higgins, horticulturist of this station. The peculiar requirements of the litchi probably are responsible for its tardy utilization both in the Hawaiian Islands and the citrus belt of the mainland portion of the United States. Its exquisite flavor has made it a favorite fruit in the Orient for thousands of years, and it is expected that, with a proper understanding of the requirements of the litchi as regards propagation and culture, its extensive cultivation in the warmer portions of the United States will be attended with success.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

Dr. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON, *Secretary of Agriculture.*

THE LITCHI IN HAWAII.[1]

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INTRODUCTION.

Many tropical fruits, hitherto unknown or neglected outside their native countries, are now receiving attention, not only in the markets of the Temperate Zone, but among growers in the Tropics and in subtropical regions, where some of the more hardy of these fruits are being acclimatized. Within a generation the banana has passed from a rare luxury to a staple food product, the pineapple from a little known fruit used for flavoring to a highly prized article of food, sold by the millions of cases of canned as well as fresh fruit. These two fruits are but the pioneers, and others are following close after them to popularity. The grapefruit has already established itself. The avocado, the most conspicuous aspirant for popular favor at the present time, has overcome much skepticism and now appears in varieties that can be grown just outside the Tropics, hundreds of acres being planted in Florida and California, and it is prevented from becoming the basis of an important industry in Hawaii only by occasional attacks of the Mediterranean fruit fly, which place this fruit on the quarantine list in the Pacific ports of the United States and Canada.

The litchi, the subject of this bulletin, is another of these tropical or subtropical fruits which is just beginning to attract commercial attention outside of China, its native country, where it has been cultivated for centuries. To the people who have lived upon the shores of the Pacific the litchi "nut" is a more or less familiar article of food, especially at the season of the Chinese New Year. Few of those who dwell east of the Philippines, however, have seen the fresh fruits which, when dried, form the litchi nuts of commerce. In most varieties the ripe fruit has an outer shell-like covering of brilliant red, giving a dish of them a striking resemblance to large strawberries. The flesh within this tough outer covering is white with

[1] *Litchi chinensis* (*Nephelium litchi*), natural order Sapindaceæ. For further discussion of the botanical status and relationships see p. 20.

about the consistency of a Muscat grape. Its delicious flavor makes the litchi highly prized by those who are familiar with it. In Honolulu the limited crop is retailed at prices ranging from 50 to 75 cents per pound (Pl. I, fig. 2). Borne in clusters (Pl. II) on medium-sized trees with dark-green foliage, these fruits usually mature about May or June in Hawaii. Like the banana and pineapple, the litchi is practically immune to the attacks of the Mediterranean fruit fly, and as it stands shipment well, it is peculiarly a commercial fruit.

Because of the desirability of increasing greatly the cultivation of the litchi in Hawaii and because of the newly awakened interest in its cultivation elsewhere, certain experiments have been conducted at the Hawaii Agricultural Experiment Station which, together with valuable data gathered from growers here and abroad, are reported in this bulletin.

COMMON NAMES OF THE FRUIT.

The name of the fruit appears in many forms as "litchi," "lichee," "litchee," "li chee," "leechee," etc. Most of these are presumably attempts at a form which represents the sound of the Chinese name, but none of them quite appears to have succeeded. The sound, as nearly as it may be represented in the English language, may be indicated by "ly-chee," with about equal stress on each part of the word. But since the form "litchi" is fixed definitely as a part of the botanical name of the tree (see p. 3), since it accurately represents the sound if the first "i" be marked long and the second short, and since this form probably is used as frequently as any other, it seems desirable that it should be adopted as the common name and that the others should be discarded.

HISTORY AND DISTRIBUTION.

References to the litchi occur in Chinese writings produced long before the beginning of the Christian era. Though it seems impossible to determine when this fruit was first brought under cultivation, it is very generally admitted that it is native to south China. De Candolle states that "it does not seem that any botanist has found it in a truly wild state,"[1] and suggests that this may be due to the fact that the southern part of China toward Siam has been little visited by botanists. Long since introduced into India, Ceylon, and other parts of the Orient, the litchi now extends to southern Japan, Formosa, Australia, and Mauritius. In comparatively recent years, it has found its way into the Western Hemisphere and is grown in Brazil and in some of the West Indies, though in the latter region it is rare.

[1] Origin of Cultivated Plants, London, 1884, p. 315.

FIG. 1.—A WELL-GROWN LITCHI TREE. THIS IS THE FIRST LITCHI TREE INTRODUCED INTO THE HAWAIIAN ISLANDS.

FIG. 2.—A BASKET OF LITCHI FRUITS SOLD IN HONOLULU FOR $25 AT CURRENT MARKET PRICES.

A CLUSTER OF LITCHI FRUITS, SHOWING THE MANNER IN WHICH THEY ARE BORNE ON THE TREES.

Mr. Ching Shai, of Honolulu, is authority for the statement that the first litchi tree was brought to Hawaii about the year 1873 by Mr. Ching Check. The tree was planted on the property of Mr. C. Afong and is now the best known of the litchi trees in Honolulu (Pl. I, fig. 1). Usually it has borne fruit abundantly, and the crop of this single tree is said to have sold at prices ranging from $75 upward in ordinary years, so rare and so highly prized is this fruit. Other introductions have been made by the United States Department of Agriculture and by Messrs. Sing Chong, Wong Kwai, Wong Leong, Luke Chan, E. W. Jordan, and others. In transit and immediately after arrival the rate of mortality among the plants usually has been extremely high, so that comparatively few trees have become established. In one instance where 400 trees were imported, only four are said to have survived. These losses have been due in part to the shipment of plants without an established root system and in part to the long voyage, followed by the treatment necessary to prevent the introduction of dangerous insects and diseases. In order to introduce and establish the choicest varieties it will be necessary to make special arrangements to insure their safe arrival. It is probably because of the difficulty of transporting the plants, the impossibility of shipping the seed under ordinary conditions, the slowness of the present cumbersome methods of propagation, and the extreme tardiness of many seedlings in coming into bearing that the litchi is represented by only a few trees in countries where the soil and climatic conditions favor its extensive production.

The litchi is believed to have been introduced into Florida about 1886 or 1887. Since that date several introductions have been made by the United States Department of Agriculture and by private nurserymen. Very many of these trees died before they became established. Of the few that now remain some are said to promise success. In a letter to this station under date of August 29, 1916, Mr. W. S. Taylor, of Tampa, Fla., stated that litchi trees sent him by the Office of Foreign Seed and Plant Introduction, of the Department of Agriculture, fruited in July. Mr. Taylor, who is familiar with the litchi in China, reports that the Florida fruit was "exceptionally large and fine." Although it has taken many years to demonstrate the possibility of the litchi's fruiting in Florida, an ardent hope is now revived that with suitable varieties the litchi may become the basis of an industry.[1]

The first litchi tree to be introduced into California is said to have come from Florida and was planted by Mr. E. W. Hadley in Santa Barbara about 1897. This tree was obtained as a small plant from Reasoner Bros., Oneca, Fla.[2] Mr. E. N. Reasoner states that this

[1] The recent freeze in Florida, when, on Feb. 3, 1917, the temperature went to 26° F., killed six-year old trees to the ground, but they appear to be sprouting up again.—D. G. Fairchild.

[2] Letter to Mr. Peter Bisset, Office of Foreign Seed and Plant Introduction, United States Department of Agriculture, dated Jan. 14, 1916.

California tree was originally imported from Saharanpur, India. It first fruited in 1913. It is possible that varieties from the hill country of India may prove best adapted to California and Florida conditions. The United States Department of Agriculture has placed a number of litchi trees in different parts of California, and the writer distributed a considerable number of seeds in that State in July, 1914.

NATURAL REQUIREMENTS.

The litchi appears to belong just within or near the border of the Tropics. When the tree is young it is very sensitive to frost, but when mature it is reported that considerable cold is endured without injury. Mr. A. C. Hartless, superintendent Government Botanical Gardens, Saharanpur, India, states, in a letter to the writer, that the trees "have been known to stand 11° of frost." In south China the litchi is grown on comparatively low lands, but nearer the Equator in India its cultivation is extended to considerable elevations. Definite data are not available as to the optimum atmospheric moisture, but the evidence indicates that a rather high humidity is desirable. Abundant rainfall is important unless irrigation is applied, but heavy rains during the flowering season are injurious. It is believed in China that electrical storms interfere with the production of flowers and fruit. Whether this be well founded or not, it may be worth while to record that the 1916 crop in Honolulu was a total failure and that the few months preceding the flowering season witnessed some of the most severe electrical storms that have occurred in the city in many years.

A deep, moist, alluvial soil seems best adapted to the needs of the litchi, but it prospers in a rather heavy and compact soil. In China, a favorite place for planting is along the banks of streams or on the dikes between rice fields. Though the litchi has been grown chiefly in very heavy soils in Hawaii, in the absence of exhaustive experiments it is impossible to state positively that it would not do equally well in light soils, provided the moisture requirements were well maintained.

CULTURAL REQUIREMENTS.

Much is yet to be learned regarding the cultural requirements of this tree. No orchard experiments with the litchi are on record in any of the meager and fragmentary literature available on the subject. Unless there is a liberal rainfall or a constant subterranean supply of water, abundant irrigation is necessary. It is well known also that large quantities of fertilizer are used in the cultivation of the litchi. It is the custom of some of the Chinese growers to apply night soil several times during the year. For this purpose a shallow trench, dug near the ends of the roots of the tree, is filled with the fertilizer which is covered with soil. Duck manure also is a favorite

fertilizer with the growers of the Orient. Some growers prefer to put the manure on as a top-dressing and cover it with a heavy mulch because of the tendency of the litchi to form surface roots. No experiments with chemical fertilizers have been reported.

Considerable difference of opinion appears to exist with regard to pruning, some growers stating that no pruning should be practiced, others insisting that the breaking off of the ends of old branches is beneficial. The customary manner of gathering the fruit, by breaking with it branches 10 to 12 inches long, provides in itself a form of pruning which some growers insist is necessary for the continued productivity of the tree, but here also there is much need for more exact data.

The trees should be planted at least 30 feet apart, and under good conditions they will require even more space before they have attained full size. Opinions differ as to the value of shade, but young trees in a country of clear skies doubtless will benefit by some protection from direct sunlight. It is important that the plantings be protected from heavy winds at all times, but particularly during the flowering season. For this purpose a sheltered spot should be chosen as a site for the plantings, or windbreaks should be provided in a region where strong winds prevail.

PROPAGATION.

SEEDS.

The litchi reproduces readily by seeds, this being the simplest method of reproduction, since most of the varieties of this fruit produce viable seeds which germinate quickly. In experiments conducted at this station it has been found that some seeds will begin to germinate within three days after planting.

Preservation.—The seeds are extremely short lived, retaining their viability not more than four or five days under ordinary conditions. Experiments to determine the longevity of these seeds under different conditions were carried on during the summer of 1915. In Honolulu in June, 1915, seeds exposed to the air under normal humidity conditions began to shrivel in less than 24 hours, and the percentage of germination fell rapidly as the period of exposure was prolonged two, three, four, and five days. After the fifth day practically all seeds were dead. In dry charcoal or similar dry material the loss of moisture and consequent loss of viability proceeds almost as rapidly as in the air. Seeds so kept for one week entirely failed to germinate.

It therefore appears that to preserve the germinability of litchi seeds it is necessary to prevent in some way the loss of moisture. In the fruit the seed is protected to a considerable degree, but in a dry atmosphere the rapid drying of the aril causes, after a few weeks, a marked loss of viability, varying with atmospheric conditions.

Fruit spread out in direct sunlight quickly changes to litchi "nuts," but if closely packed in a closed room remains moist a fairly long time.

In refrigeration the fruits retain their freshness much longer, and the seeds appear uninjured, although no data are at hand relating to the germinating power of litchi seeds from fruits kept at low temperatures for periods longer than two weeks. From the fact that seeds of fruits stored for two weeks at about 38° F. gave perfect germination, it would appear that seeds may be kept for a considerable period by this method without injury. No tests of refrigeration as a means of preserving seeds separated from the fruit have been made in Hawaii.

Keeping the fruits in distilled water for two or three weeks did not appear to injure the seeds seriously, and this method may be used to preserve the seed where refrigeration is not available.

Moist sphagnum moss appears to be one of the best media for the preservation of the seeds in transit. In experiments at his station the moss was first saturated with water and then wrung by hand in a piece of burlap until as dry as possible. So treated it contained water equal to 212 per cent of its own weight when air dried. A layer of this moist moss about an inch thick was spread upon a sheet of heavy waxed paper, the seeds distributed at regular intervals upon it and covered with another layer of moss of equal thickness. The package was then rolled, wrapped with a layer of crimped strawboard or corrugated paper to prevent breaking the waxed paper, and finally covered with a heavy manilla wrapper. Thus packed, seeds were shipped by mail to Florida, many packages being sent in this manner and all reported as arriving in excellent condition. Similar packages were held at the station for periods varying from two to eight weeks. After being kept as long as eight weeks in this moist medium the seeds had germinated and produced sprouts so large as to require extreme care in handling to avoid injury. However, a large majority of the plantlets could be saved even after so long a period, which, it will be observed, is sufficient for mail shipment to almost any part of the Tropics. It is probable that less moisture than was used in the moss in the experiments would prevent the drying out of the seeds and would retard germination. A mixture of finely cut sphagnum and powdered charcoal slightly but uniformly moistened and placed in a tin tube serves the same purpose.

Sowing.—From the foregoing facts it is apparent that the seeds ought to be sown at the earliest possible moment after they are removed from the fresh fruits, necessary delays even of one day requiring special precautions to prevent deterioration. They should be sown in pots sunk in well-drained soil. If small pots are used,

precautions must be taken to prevent the drying out of the soil by evaporation from the sides of the pots. This may be done by placing the pots in moistened moss, sawdust, or sand from which any salt which may have been present has been washed. The seeds should be placed horizontally about one-half inch beneath the surface of the soil, and the young seedlings should be partially shaded.

LAYERING.

As seeds do not reproduce the variety from which they have been taken, and as the seedlings are of rather slow growth and require many years to come into bearing, it has for many years been the custom in China, the land of the litchi, to propagate the best varieties by layering or by air-layering, a process which has come to be known as "Chinese layering" and is applied to many kinds of plants. In air-layering, a branch is surrounded with soil until roots have formed, after which it is removed and established as a new tree. In applying the method to the litchi, a branch from three-fourths inch to 1½ inches in diameter is wounded by the complete removal of a ring of bark just below a bud, where it is desired to have the roots start. The cut usually is surrounded by soil held in place by a heavy wrapping of burlap or similar material, although sometimes a box is elevated into the tree for this purpose. Several ingenious devices have been made to supply the soil with constant moisture. Sometimes a can with a very small opening in the bottom is suspended above the soil and filled with water which passes out drop by drop into the soil. Again, sometimes the water is conducted, from a can or other vessel placed above the soil, by means of a loosely woven rope, one end of which is placed in the water the other on the soil, the water passing over by capillarity.

Air-layering usually is commenced at about the beginning of the season of most active growth, and several months are required for the establishment of a root system sufficient to support an independent tree. When a good ball of roots has formed, the branch is cut off below the soil, or the box, after which it generally is placed in a larger box or tub to become more firmly established before being set out permanently. At first it is well to provide some shade and protection from the wind, and often it is necessary to cut back the top of the branch severely, so as to secure a proper proportion of stem to root.

Some modifications of this old-world method have been practiced with success at this station. One of these consists in using a long trough-shaped box, in which several branches may be rooted at the same time, thus increasing the number of plants which may be propagated with a given amount of labor and attention. For this purpose rather small branches not more than a half-inch in diameter are laid across the trough through notches cut in the sides of the box. With

the low trees used here, it has been much more economical to apply the water by hand daily than to prepare the contrivances mentioned above for maintaining the moisture. When the branches have established root systems, the box is removed from the tree and the soil washed out carefully with a stream of water. This process, without injuring the roots, permits easy separation of the rooted stems of the different branches, if these have not been allowed to remain too long on the tree. Plate III, figure 2, shows one of these troughs with rooted branches which are being removed to be established as independent plants.

Another modification of layering, used successfully on low trees or on trees which can be surrounded easily by a platform, consists in the use of small branches, not more than a quarter of an inch in diameter, laid through one side of a gallon tin cut for the purpose. These make small plants, but many more can be taken from the tree without reducing its size seriously. It is too early to state how long it may take these little plants to catch up with those that have been started from larger branches.

Although layering has the advantage of exact reproduction of varieties and rapid fruiting, nevertheless, it is a slow and cumbersome method not well adapted to the rapid multiplication of varieties usually desired by American nurserymen. There is also ground for the belief that its excessive use may have a devitalizing effect upon the parent tree. Girdling for the purpose of forcing heavy production of fruit is generally believed to have such an effect upon litchi trees, perhaps because the root system and other parts of the parent tree are robbed of the energy used in forcing fruit production in the girdled branches. It is not unreasonable to suppose that something of the same effect may follow the production of new root systems on many branches. While no definite data can be recorded, there is some evidence supporting this belief.

BUDDING AND GRAFTING.

With the exception of a limited use of inarching, the practice of budding or grafting, almost universally employed in the commercial culture of fruit trees and vines in America and Europe, is scarcely ever applied to the litchi. A number of trees have been spoken of in a general way as budded trees of the litchi, but closer investigation has proved them to have been layered. Aside from the advantages of speed and facility in multiplication, budding and grafting afford the opportunity to use, as root stocks, other varieties or species, which may offer as decided advantages in the case of the litchi as are well known to exist in the case of many other fruit trees. For example, the litchi grows slowly and frequently requires eight or nine years in Hawaii to come into bearing, even when grown from layers. Related species which are of more rapid growth, are known, and these should

be tested as stocks for the litchi. It is probable also that stocks may be found which will increase the hardiness of the litchi and thus make it possible to cultivate it outside of the Tropics. Resistance to disease and insect attack also is to be considered, and in this connection it is worth while to mention the apparent immunity of the longan (*Euphoria longana* or *Dimocarpus longan*) to the attacks of the erinose mite,[1] which is destructive to the foliage of the litchi if not held in control. While the Chinese have not used other species for stocks, in their inarching varietal preferences have been discovered. Mr. G. Weidman Groff states that the variety Loh Mai Chi is inarched generally upon the variety San Chi about Canton.[2]

Experiments in grafting and budding the litchi on the longan have received some attention at this station. A method of bark grafting has proved thus far successful as a means of uniting these two species, now usually classified as of different genera. This has been used so far only in top-working the longan trees. The method consists in cutting off branches from 1 to 2 inches in diameter and immediately inserting in these small scions of mature wood from the desired variety of litchi, making incisions in the bark, beginning at the top of the cut in the stump and running down 3 or 4 inches. This process is illustrated in Plate III, figure 1. The wound is smeared with grafting wax, while the scion and top of the stock are covered with a heavy paraffined paper bag. The bag is tied about the branch to prevent excessive transpiration, as this would destroy the scion before it could become united to the stock. After about three weeks this may be removed, as it has been found that the scion united with the stock by that time.

Repeated experiments with this method have shown that there is no great difficulty in securing a union of the litchi with the longan (Pl. IV, fig. 1). A noteworthy influence of the stock on the scion should be mentioned here. The growth produced is very much more rapid than that of the litchi on its own roots, and in some cases the character of the foliage appears to undergo a change. It is, of course, too early in these experiments to know anything about hardiness, resistance to disease, kind of fruits, or many other important features.[3]

The budding of the litchi on the longan has been accomplished in Hawaii, but this method is not so successful as that of grafting described above.

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[1] Vide, p. 17.

[2] U. S. Dept. Agr., Bur. Plant Indus., Plant Immigrants No. 111–112 (1916), p. 908.

[3] Since the above was written, attention has been called to repeated failures to make effective and permanent unions between these two genera where this work has been tried in Washington, D. C., and in Florida. Unions are reported to have been made but they have not been permanent. This is not an uncommon result when grafting is attempted between widely different plants. At this time (Mar. 3, 1917), the Hawaii Experiment Station plants are in a flourishing condition, this being thirteen months after the setting of the scions. None has been lost since the first few weeks, when two failed. It is, however, too soon to know whether these unions will be permanent.

THE LITCHI CROP.

The litchi ripens fruit at different times in various countries, May and June being the season in Hawaii, while July is midseason in China.

The bearing age of the litchi is extremely variable, particularly if the trees are grown from seed. Seedlings in Hawaii have been known to fruit in five years, while others have continued to grow and thrive for over 20 years without producing a single flower. That this is not always due to cultural and natural conditions is demonstrated by three layered litchi trees and one seedling growing in the same yard under practically identical conditions, the layered trees having borne regularly, while the seedling tree, now 24 years old and over 30 feet high, has never produced flowers. Numerous instances of this character have given rise to the general statement that seedling litchis do not come into bearing until they are 20 or more years old, but a number of cases are on record to disprove the universality of this statement. Wide variability in the age of coming into bearing has been noted with seedlings of other tropical fruits, especially the avocado, but the litchi appears most extreme in this respect.

Layered trees, if rooted from large branches, frequently flower in one year in China, although under the best methods of cultivation the first year's flowers are removed to prevent exhaustion by fruit bearing, a proceeding sometimes followed during the second year. Under Hawaiian conditions, however, even layered trees commonly do not bear as young as do the trees in China, several years usually elapsing before any fruit is produced. The fact that most of the trees of which record exists in Hawaii have been planted on uplands may cause their comparative tardiness in coming into bearing. This possibly may be overcome when the needs of the tree are understood more clearly and supplied more definitely.

The productivity of the litchi is said to last for centuries in its native home, and while it would not be safe to depend upon such allegations, it is a well-established fact that the tree continues to produce liberal crops of fruit through many years.

From the limited data on the litchi in Hawaii, the yield of fruit of a good, mature tree may be placed at 200 to 300 pounds per season. Some trees are reported to have produced about 1,000 pounds.

As has been stated, in picking the fruit it is customary to break off branches 10 to 12 inches long with the clusters, which are taken to market in this condition and sold by weight, including the branches and leaves. In some fruits, bought on condition that no branch exceed 5 inches in length below the fruits, it was found that the sticks constituted 3 per cent of the total weight. In an analysis of this particular lot it was found that the seeds constituted 17.03, the skin, or shell, 7.86, and the flesh 75.1 per cent of the weight of the fruit.

The fruits of the litchi very quickly lose their bright color and with it their attractive appearance in the market. It is important to pre-

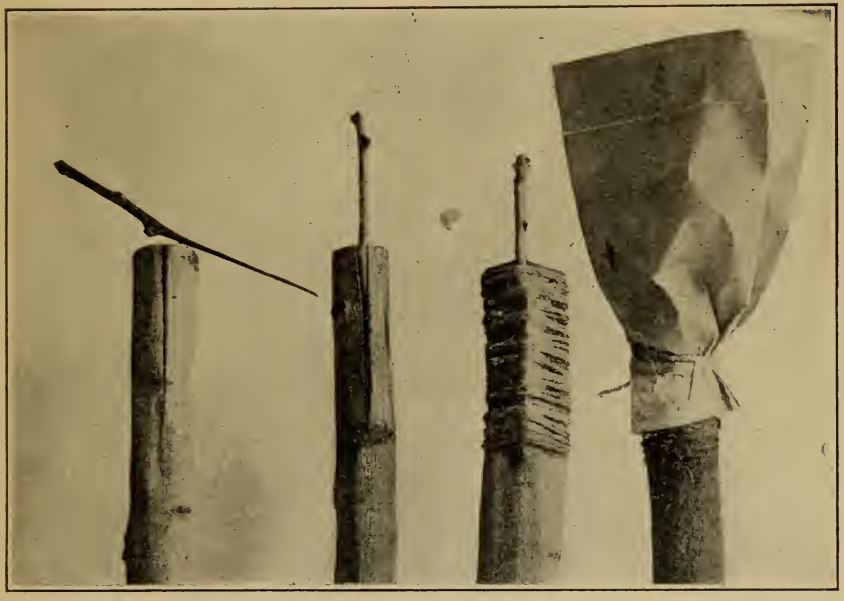

FIG. 1.—GRAFTING THE LITCHI ON THE LONGAN BY THE BARK-GRAFTING METHOD.

FIG. 2.—A METHOD OF AIR-LAYERING THE LITCHI.

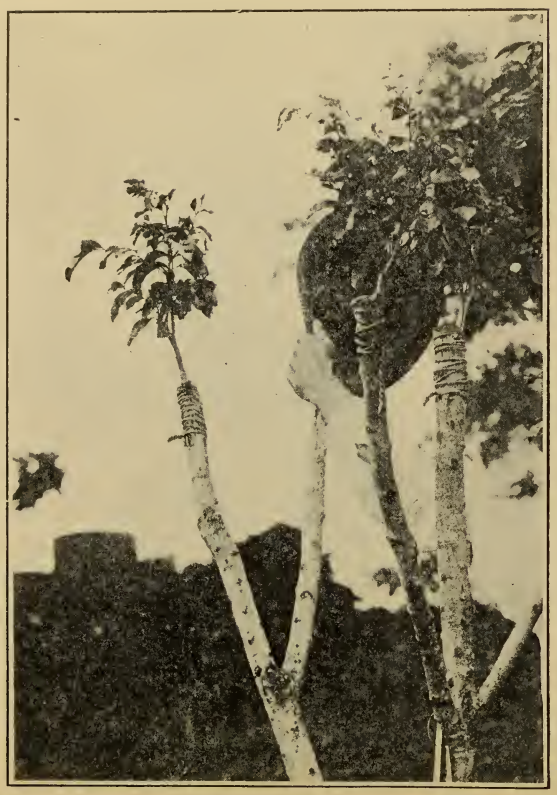

FIG. 1.—THE LONGAN TOP-WORKED TO THE LITCHI.

FIG. 2.—ERINOSE OF THE LITCHI. UPPER SURFACE OF LEAF, SHOWING ELEVATIONS OR GALLS.

serve the color in order to realize the full value of the fruit. The Chinese sometimes sprinkle the fruits with a weak salt solution and pack them in bamboo, sealed at each end with clay, for shipment to distant markets.[1] In experiments at this station it was found possible to keep the fruits in distilled water for about two weeks with only slight deterioration in appearance and flavor, a practice sometimes followed in the Orient. Refrigeration, where it is available, furnishes the best means of preserving the litchi for a limited period in its natural state. No experiments on the prolonged use of refrigeration have been reported. Fruits shipped in refrigeration from this station to San Francisco and thence without artificial cooling to Washington, D. C., and to Florida, are reported to have arrived in good condition, although some loss in color must have occurred after the fruits were removed from refrigeration. Refrigerated fruits under observation in transit from Honolulu to San Francisco, and still others kept in Honolulu, showed no loss in color or flavor. These were held in refrigeration about two weeks before examination. There is no doubt that refrigeration will provide a very satisfactory method for placing upon American markets the litchi crop grown in Florida, California, Hawaii, Porto Rico, or Cuba.

Litchi "nuts," which are simply the dried fruits, are prepared either by sun drying or by artificial heat, the sun-dried "nuts" usually commanding the higher price. The drying process begins very soon after the fruits are exposed to free ventilation and to direct sunlight. A large part of the litchi crop of China is marketed in the dried form and finds its way to many parts of the world. Considerable quantities of the fruit also are canned in sirup.

THE LITCHI AS FOOD.

THE FRESH FRUIT.

An analysis of fresh litchis, made in June, 1915, by Miss Alice R. Thompson, assistant chemist of this station, gave the following results:

Analysis of fresh litchis.

	Per cent.
Edible portion	51
Waste (seeds and shell)	49
Total solids	20.92
Insoluble solids	1.79
Ash	.541
Acids as sulphuric acid	.16
Protein	1.15
Reducing sugars	12.5
Sucrose	2.8
Total sugars	15.3
Direct polarization at 29° C., °V, 0.3.	
Invert polarization at 29° C., °V, 3.2.	

[1] U. S. Dept. Agr., Bur. Plant Indus., Plant Immigrants No. 111–112 (1916). p. 916.

By comparing the figures of this analysis with those given on page 12 it will be seen that the waste portion here is much greater. Although neither lot of fruit had small seeds, yet the size of those in Miss Thompson's analysis was unusual, which accounts for the large proportion of waste in the total weight. The analysis, however, serves to show the excellent composition of the flesh of this unusual fruit.

A taste for the fresh litchi does not have to be acquired, as the flavor appeals to nearly everyone. Wherever the litchi is known it is prized as one of the best of tropical fruits. The pulp is meaty, much like that of a white Malaga grape, and the flavor is very pleasant. The raw pulp, freed from seed and shells, makes a palatable dish.

THE PRESERVED FRUIT.

A number of experiments were conducted at this station by Mrs. J. M. Westgate on various ways of preparing and preserving the litchi for food. The fruits were freed from seeds and shells and 11 pounds and 5 ounces of the pulp used in cooking experiments. The preserving was done in June, 1915, and the jars opened in October, 1916. Heat seemed to toughen the fruit at first, but when the cans were opened a year later this toughness was found to have disappeared entirely. Some of the methods of preserving the fruit are described below.

Plain Litchi Sauce.

3 pounds fruit pulp.
1 pound white sugar
2½ cups water.

Boil the sugar and the water together until clear. Add the fruit pulp to this sirup and cook slowly without stirring for 20 minutes. Put in sterilized glass jars and seal. Wrap the jars in newspapers to exclude light. The fruit, when opened, is almost white in color with a flavor very like fresh litchi.

Spiced Litchi.

1 pint water.
2 pounds brown sugar.
1 ounce stick cinnamon.
2 cloves.
Litchi pulp.

Boil the sugar, water, and spices together until the sugar melts. Add fruit pulp till the sirup barely covers it and cook slowly for 20 minutes. Place in sterilized glass jars and seal. The fruit is flesh colored and of a very delicate flavor when opened.

Sweet Pickled Litchi.

1 pint water.
2 pounds brown sugar.
1 ounce stick cinnamon.
2 cloves.
½ cup vinegar.
Litchi pulp.

Boil water, sugar, vinegar, and spices until the sugar melts. Add to this sirup all the fruit pulp it will cover and cook slowly 20 minutes. Place in sterilized glass jars and seal. The fruit, when opened, is very tender, with a raisin flavor and a whitish flesh color.

DRIED LITCHI.

Fruit pulp, freed from seeds and shells, was put on a china plate and dried in the sunlight for nine successive days. It was very sticky at first, then it developed the texture and flavor peculiar to the dried litchi of commerce and a reddish-brown color about like that of raisins. The reduced bulk, due to the removal of the shells and seeds, hardly offset the labor and the greater danger from dust and ants and other insects, while the flavor was practically the same as that of the litchi nut.

CANNED LITCHI.

A pint can of litchi was bought in a Chinese store in Honolulu, which had presumably been canned in China. The seeds and shells had been removed without marring the shape of the fruits, which looked somewhat like big white California cherries and had the flavor of the plain litchi sauce canned at this station.

INSECTS AND MITES.

Several species of insects and at least one species of mite cause damage to the litchi tree or fruit. Most of these are of minor importance, but they are mentioned here as a matter of record and in order that anyone cultivating litchis may be on the lookout for them.

It is worthy of special notice that the Mediterranean fruit fly apparently does not breed in sound litchis. In the multitude of observations made by entomologists no record has been found of the litchis having been attacked by this fly except where the fruit has been broken open by other means and the pulp exposed. In this respect, therefore, the litchi may be classed with the banana and pineapple as practically immune to attacks of this insect in its normal state.

The litchi fruit worm, the larva of a tortricid moth (*Cryptophlebia illepida*), has caused considerable damage to the fruit crop at times. In its report for 1910, the entomological division of this station records that in one case practically the entire crop of a private orchard was destroyed, but in the following year, when attempts were made to prevent loss by spraying, the moth, though apparently doing little damage to the small litchi crop, was present as usual in klu (*Acacia farnesiana*) and in pods of koa (*Acacia koa*). The moth

has been found in litchi fruit about three-fourths grown, with only a slight brown point as external evidence of the presence of the insect. The larva lies embedded in the flesh, apparently not affecting the seed, though it is not certain that the seed of infested fruit will reach maturity. As the larva develops within the fruit the latter splits open and becomes worthless. No experiments have been completed to determine methods for the control of this pest, but from the nature of the attack it appears that arsenicals probably would be effective, arsenate of lead being perhaps the most promising.

A root-inhabiting mealy bug, apparently a species of Pseudococcus, has been found doing considerable damage to plants undergoing the process of layering. These insects were found in large numbers on the callus formed where the branch had been girdled to cause the formation of roots. In a number of cases no roots were produced, apparently because of the heavy demands of the insects upon the supplies of material at this point. Where the presence of these insects is suspected, the soil should be removed from the callus and the insects destroyed, either with a solution of some contact poison, as the oil emulsions, or a very small amount of carbon bisulphid placed in the soil at some distance from the callus. If placed in the soil and covered, carbon bisulphid, which is quite volatile, will penetrate to all parts if the soil is not excessively wet. If the liquid comes in immediate contact with plant tissues it destroys them.

The hemispherical scale (*Saissetia hemispherica*) occasionally infests weak litchi trees. This is a waxy, soft scale, brown to dark brown in color, and a well-known pest of several kinds of tropical fruit trees. Partly held in check by natural enemies, it is not difficult to control with contact poisons such as the oil emulsions.

The Japanese beetle (*Adoretus tenuimaculatus*) has been known to attack very young litchi trees, but it can hardly be considered an ordinary pest of this plant. Vigorous trees usually are not infested, and sufficient protection during the critical period is afforded by arsenical sprays, such as arsenate of lead. The natural enemies of the beetle should also be encouraged.

The larvæ of a moth (*Archips postvittanus*) occasionally cause some injury to the foliage and the flowers. The habit of this insect in its attack upon the litchi, as well as upon the avocado and several other fruit trees and shrubs, is to sew together the edges of the leaves so as to make a convenient hiding place from which it can go out to feed. It may also weave a web about the flowers and destroy them. An arsenate of lead paste, containing 15 to 16 per cent of arsenic oxid and used in the proportion of 8 pounds to 100 gallons of water, will control these larvæ effectively when they appear in any considerable numbers.

FIG. 1.—ERINOSE OF THE LITCHI. UNDER SURFACE OF LEAF, SHOWING DIFFERENT STAGES IN THE DEVELOPMENT OF THE DISEASE.

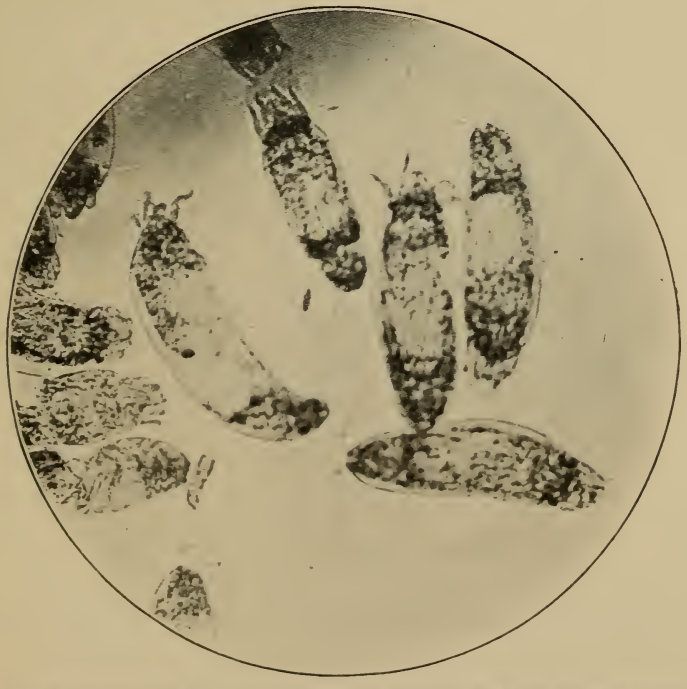

FIG. 2.—ERIOPHYES SP., AN UNDESCRIBED SPECIES OF MITE WHICH IS THE CAUSE OF THE ERINOSE DISEASE OF THE LITCHI.

Photomicrograph by P. J. O'Gara.

ERINOSE.

SYMPTOMS.

On February 3, 1916, attention was called to a disease or injury of the litchi caused by mites which is here designated as erinose because of its similarity in appearance and cause to the erinose of the grape and other plants. The tree most affected is the oldest and has been one of the most prolific litchis in Hawaii, while within 100 feet of it two younger trees were found slightly affected.

In the early stages of the malady small galls or wartlike swellings, often not more than one-sixteenth of an inch in diameter and half as high, appear upon the upper surface of the leaf without producing any discoloration. On the under surface may be seen brown spots, which very early begin to form depressions corresponding to the swellings upon the upper surface. The galls increase in size as the trouble progresses and may become an inch or more in diameter. (See Pl. V, fig. 1; Pl. IV, fig. 2.) Frequently the affected areas become confluent, involving nearly the entire leaflet and giving rise to a much crinkled condition of the upper and a brown velvety covering on the under surface. Plate V, figure 1, center, shows a leaf in which all the leaflets are involved and only a few small areas remain green. The velvety covering may extend also to the petiole or leaf stock, and in advanced stages it is found even on the young twigs.

A powerful hand lens shows that the velvety covering is composed of innumerable trichomes (plant hairs), and the trained eye occasionally can distinguish the mites which are the cause of the trouble, though these will escape the attention of anyone unfamiliar with them. With a compound microscope, magnifying about 40 diameters, the mites are plainly visible in vast numbers among the trichomes.

Specimens of this mite have been submitted for identification to Dr. L. O. Howard, Chief of the Bureau of Entomology, of the Department of Agriculture, who reports that the mite is apparently an undescribed species of Eriophyes (Pl. V, fig. 2), the genus responsible for similar diseases of other plants.

REMEDIES.

On February 11, 1916, three different treatments were tried. The tree which was most severely attacked was sprayed with a solution of 10 ounces nicotin sulphate and 1¾ pounds whale-oil soap in 50 gallons of water. This tree, about 48 feet in height and 48 feet in spread, received 50 gallons of spray in the attempt to reach every part. The second tree, with a height of 20 feet and a spread of 28 feet, was treated with 4¾ pounds of resublimed flowers of sulphur

in powdered form, applied with an ordinary powder bellows. The third tree, with a height of 24 feet and a spread of 30 feet, was sprayed with self-boiled lime-sulphur solution made up of 4 pounds quicklime and 4 pounds flowers of sulphur in 25 gallons of water, to which 2 pounds of arsenate of lead was added to kill an occasional larva of *Archips postvittanus*.

Fresh material from the treated trees was gathered and examined on February 19. That from the first tree sprayed with nicotin sulphate and fish-oil soap, revealed only 10 living Eriophyes after a search for a half hour with a microscope. On the second tree, which had been treated with flowers of sulphur in powdered form, many dead but also many living mites were found. The material from the third tree, which had been sprayed with self-boiled lime-sulphur, showed few Eriophyes where the spray had settled, but in places that had escaped many were living.

The treatment was repeated on February 26, 1916. Later examination disclosed results so much more favorable to the nicotin sulphate and fish-oil soap that the other treatments were abandoned. This spray was applied again on March 28, and April 11 and 25. One tree received treatment on March 11. By the end of April the mites were practically eradicated.

IMMUNITY OF THE LONGAN.

A longan tree, situated about midway between two of the diseased litchi trees referred to above and less than 50 feet from either, has presented no indication of erinose, and a search of the leaves has revealed no Eriophyes, although certain other mites are present, producing a yellowish-powdery effect, not uncommon on mite-infested plants.

VARIETIES.

There are many varieties of litchi, propagated by the air-layering or "gootee" method referred to above and cultivated under varietal names. The origin of most of these varieties is unknown in this country, and, indeed, the origin of some of them is so ancient that it is doubtful whether the most careful research in the lands to which they are indigenous would reveal anything of value concerning them. It is probable that most kinds have originated as chance seedlings, although some may have arisen as bud mutations. Fruits of established identity are not available for the making of accurate pomological descriptions of any of the varieties, and no full descriptions have been found. The following list of choice varieties in China, with valuable notes concerning each, has been taken from a report by United States Consul F. D. Cheshire:[1]

[1] U. S. Dept. Agr., Bur. Plant Indus., Plant Immigrants No. 111–112 (1915), pp. 918, 919.

1. *Yuk-ho-po*—"jade purse"—having a thick skin, green color, a large kernel, and a sour taste. It is inferior in quality, but as it is the first to make its appearance, coming in about the 5th of May, it is given a good reception.

2. *Hark-yip*—"black leaf"—dark red in color, delicate skinned, fragrant, and sweet. This is one of the best lichees and comes into bearing about June 6. The best of this variety is produced in the Tung Kun district and the Shui Tung district. It is plentiful in the market and very popular.

3. *Kat-jat-kwo*—"coackroach fruit"—dark red, thick skinned, pear shaped. This fruit is inferior in quality.

4. *Wai-chi*—"wai fruit"—the most common variety of lichees on the market in Kwangtung Province. Some are light and some are dark red in color, and are thin skinned. It is produced between the 21st of May and the 21st of June and is considered a good variety.

5. *Chui-ma-chi*—"green-spotted lichee"—of a green color and sour taste. There are very few in the market.

6. *Tong-pok*—"sugar sheets"—of a dark red color, pear shaped, and sweet flavor, but not of a delicious taste. It is produced for the most part in the Namhoi and Samshui districts.

7. *Kwai-mi*—"cinnamon flavor"—light red, rough skinned, small kernel, very fragrant and sweet. One of the best varieties of lichees. It is placed on the market about June 21. The best are obtained from Lo Kong Tung, in the Pun Yu district.

8. *Shan-chi*—"hill fruit"—of a red color and round shape, slightly sour.

9. *Hom-shiu-chi*—"magnolia fruit"—light red, small sized, sweet tasting, but not delicious. Attached to each lichee of this species is a smaller green one.

10. *No-mai-chi*—"glutinous rice cake." This is one of the most popular lichees, thin skinned, fragrant and sweet, and good appearance. It has a very small kernel and a heavy pulp. It is produced in the month of June and comes mostly from Pun Yu and Canton.

11. *Fei-tsze-siu*—"smiling imperial concubine"—half red, half green, round shaped, thick rough skin; good flavor, with a slightly sour taste. It is produced at the end of June, mostly in Shiu Kwan and Ying Tak, and is considered a good fruit.

12. *Chun Fung*—"phoenix lichee"—small, round, of a red color and thick skin; not good in taste.

13. *Heung-lai*—"fragrant lichee"—produced in the Sun Hing district; small and round, of a red color and rough skinned; fragrant and sweet. It was formerly an article of tribute to the throne. The *heung-lai* is produced at the end of June.

14. *Kwa-luk*—"green mounted lichee." This lichee is grown in the Tsang Shing district. Its characteristics are a round shape, fine skin, and delightful red color; fragrant and sweet. It is considered superior to the *no-mai-chi* and the best lichee that can be had in Kwangtung Province. It is difficult to obtain in the market. This species usually grows in pairs—one large red, and the other a small green. The green one is not edible. The genuine *kwa-luk* is grown from only one tree, which is inside the Tsang Shing magistracy. During the Manchu régime the fruit of this tree was accepted as tribute by the Emperor. The lichees of this variety grown in the neighborhood are also considered as good fruit, but they are almost monopolized by the officials. The *kwa-luk* lichee is chiefly used for presentation purposes between officials, from two to eight lichees being placed in one box. The genuine *kwa-luk* can be obtained only with great difficulty.

15. *Sheung-shu-wai*—"Chancellor's wai-chi"—produced in the Tsang Shing district. It resembles the *wai-chi* in appearance, but its taste is that of the *no-mai-chi*. It is one of the best varieties of the lichees and is placed on the market about the 7th of July.

In India several varieties are very highly esteemed. A variety known as "McLean" is said to be one of the best in that country. Another under the name "Muzaffarpur Seedless," is practically seedless in many of its fruits. "Bedana" is another small-seeded, sweet variety. "Dudhia" is quite unusual in that it is white. "Rose Scented" is a fruit of large size and very agreeable flavor. "China" is a late-season variety.

BOTANICAL STATUS AND RELATIONSHIPS.

Closely related to the litchi is the longan or loongyan, *Euphoria longana* or *Dimocarpus longan*. This, which has been mentioned above,[1] is a tree attaining a height of 40 to 50 feet and producing abundant straw-yellow fruits about three-quarters of an inch in diameter. The fruits, sometimes called dragon's eyes, are borne in terminal or axillary clusters and have a shell-like covering similar to that of the litchi and a fleshy aril surrounding the seed but free from it. In texture it is quite similar to the litchi, but in flavor it is not equal to that fruit. The longan is indigenous to British India. De Candolle states that it is wild "from Ceylon and Concan as far as the mountains to the east of Bengal, and in Pegu."[2] It was early introduced into the Malay Archipelago and China, where it is now extensively cultivated for its fruits. The statement has been made that it is of slower growth than the litchi, but this certainly does not hold true under Hawaiian conditions, where it is a robust tree far exceeding the litchi in vigor and rapidity of growth. As in the case of the litchi, seedlings frequently are very tardy in coming into bearing.

Another closely related species is the rambutan (*Nephelium lappaceum*), believed to be a native of the Indian Archipelago and now cultivated very generally about Singapore and the Straits Settlements. The fruits are borne in clusters and are considerably larger than those of the litchi, with a leathery pericarp and soft fleshy spines. The rambutan apparently never has been introduced into Hawaii, probably because of the short life of the seeds and the difficulty of transporting the young trees. It is believed the careful and painstaking effort which would be required in introducing the rambutan and in testing its adaptibility would be fully repaid.

Still another of the relatives of the litchi is the pulassan (*Nephelium mutabile*), which closely resembles the rambutan but is said to be even more highly prized in its native country.

Until recently all the species mentioned above have been placed in the genus Nephelium, the litchi being designated *Nephelium litchi;* the longan, *N. longana;* the rambutan, *N. lappaceum;* and the pulas-

[1] Vide, p. 11.

[2] Origin of Cultivated Plants, London, 1884, p. 315.

san, *N. mutabile*. Recent botanists, however, separate them into the genera Litchi, Euphoria or Dimocarpus, and Nephelium, as indicated above. The characters upon which this separation is based are recorded as follows:[1]

Euphoria. Fruit tubercled with rugose, flattened, sometimes indistinct tubercles; aril free; embryo straight, radicle at the base of the seed; petals present; sepals imbricate: Includes the longan or longyen (*E. longana*, Lam. *Nephelium longana*, Cambess. See *Euphoria*). Litchi. Fruit tubercled with angular prominent tubercles; aril free, embryo straight, radicle at the base of the seed; petals wanting; sepals valvate, small: Includes the litchi (*Litchi chinensis*, Sonn. *Nephelium litchi*, Cambess. See *Litchi*). Nephelium. Fruit echinate-muricate, sometimes smooth; aril adnate to the seed; embryo curved, the radicle near the apex of the seed; petals wanting, in some species present; sepals valvate, small.

The three species mentioned above may be distinguished by the leaves as follows: The longan has usually four pairs (2 to 5) of leaflets, coriaceous, strongly veined, acuminate but more or less obtuse at point, 2 to 4 inches or more long; the litchi has usually three pairs of leaflets, coriaceous, indistinctly veined, glaucous beneath, obtusely acuminate, 2 to 5 inches long; the rambutan has usually two to three or more pairs of leaflets, chartaceous, strongly veined, often obtuse, 3½ to 7 inches long; the midrib is somewhat raised above, impressed in the two preceding species.

Other related species of Sapindaceæ might be mentioned, but only those have been included which are rather common in the Orient and which are so closely related to the litchi as formerly to have been placed in the same genus. There is a considerable number of species suitable for the experimental use of plant propagators and for the work of plant breeders.

ACKNOWLEDGMENTS.

It is desired to express appreciation here of the kind assistance rendered by several gentlemen who have long cultivated the litchi in Hawaii, including Messrs. Ching Shai, C. K. Ai, Wong Leong, and others. Much valuable information concerning the litchi in foreign countries has been received through correspondence with many botanists and horticulturists, among whom should be mentioned especially Messrs. G. Weidman Groff, of Canton Christian College, China; A. C. Hartless, superintendent, Government Botanical Gardens, Saharanpur, India; G. T. Lane, curator, Royal Botanic Garden, Calcutta; and G. S. Varma, garden overseer, Lahore, India. To all of these and others this opportunity is taken to express thanks.

[1] Bailey, L. H. Standard Cyclopedia of Horticulture, New York, 1916, vol. 4, p. 2131.

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